Two Applications of the Nuclear Thomas-Fermi Model*

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We use the Thomas-Fermi model of macroscopic nuclear properties described in [1] to discuss two applications: a) the response of the nuclear energy to changes of the neutron and proton diffusenesses, and b) the equation of state of cold nuclear matter. Under a) formulae are provided which will make it possible to improve existing Microscopic-Macroscopic calculations of nuclear properties by the inclusion of the two degrees of freedom associated with the neutron and proton diffusenesses [2]. The algebraic formulae presented under b) may serve as a reliable baseline estimate of the equation of state [3].

a) Estimating the dependence of the nuclear surface energy on surface diffuseness may turn out to be important for locating more reliably the magic numbers in the region of superheavy nuclei. In order to find the ground-state energy and shape of the nucleus the sum of the microscopic shell correction and a macroscopic energy is varied as a function of the shape degrees of freedom. In such variations the surface diffuseness is usually kept constant, but one may well ask how the results would change if the diffuseness were to be treated as an additional degree of freedom, to be varied simultaneously with the shape degrees of freedom. There have also been indications [4] that an increased surface diffuseness would begin to favour the magic proton number Z=126 over 114. This possibility of a reappearance of the magic number Z=126 would affect forthcoming searches for superheavy nuclei, and it is important to throw further light on this question by performing up-to-date macroscopic-microscopic calculations generalized to include the surface degrees of freedom.

b) There has always been considerable interest in the energy per particle of nuclear matter considered as a function of the nuclear density and the relative neutron excess. This fundamental quantity plays a key role in theories of neutron stars and supernova explosions, as well as in the interpretation of nucleus-nucleus collisions at energies where nuclear compressibility comes into play.

Direct information on $e(\rho,\delta)$ is difficult to come by for values of the density ρ away from those characterizing normal nuclei and for values of the asymmetry δ beyond the relatively small values characteristic of the most neutron-rich nuclei. One way to extrapolate beyond this limited regime is by using a nuclear model (like ours [1]) fitted to binding energies of finite nuclei and extrapolating to nuclear matter.

For very large extrapolations (several times the standard density) our simple expression for $e(\rho,\delta)$ will have to be judged by whatever experimental information becomes available, and by comparisons with theories that are considered to be intrinsically more reliable. (In this connection see [5], where our $e(\rho,\delta)$ was incorporated in neutron star studies and the results compared with those based on other theoretical equations of state.) In the meantime, because of its simplicity and firm contact with measured properties of finite nuclei, our algebraic expression for $e(\rho,\delta)$ could be used as a convenient baseline formula for the equation of state of cold nuclear matter.

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